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Adequate level of mental arousal in a cognitive task.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Study 1 examined the predictors of performance level in two types of Go/No-Go tasks. Study 1a focused on a vigilance task with rare events requiring a response in order to avoid a large loss. The results showed that both Heart Rate (HR) and Peripheral Arterial Tone (PAT) were good predictors of the ability of performers to succeed in this vigilance task. Study 1b examined a faster-paced task which required learning to differentiate between positive and negative cues (or nature conditions). In this task, PAT was the only significant predictor of performance, suggesting that it is more sensitive to acute investment of mental effort than HR. Study 2 examined the potential of using the PAT in a biofeedback system where a person is informed of his/her low arousal. The results of a pilot tests showed that individuals were able to comply with the information given by the system, and improved their performance in the intervals following the arousal cues it provided.

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DEPARTMENT OF THE AIR FORCE
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE OHIO

2 September 2008

MEMORANDUM FOR 711 HPW/IR (AFRL IRB)

FROM:

TECHNION - ISRAEL INSTITUTE OF TECHNOLOGY

Faculty of Industrial Engineering and Management
Technion City - Haifa 32000 - Israel

SUBJECT: Final report for "Adequate level of mental arousal in a cognitive task" (Protocol F-WR-2006-0084-H).

1. Status of Study: Study 1 examined the predictors of performance level in two types of Go/No-Go tasks. Study 1a focused on a vigilance task with rare events requiring a response in order to avoid a large loss. The results showed that both Heart Rate (HR) and Peripheral Arterial Tone (PAT) were good predictors of the ability of performers to succeed in this vigilance task. Study 1b examined a faster-paced task which required learning to differentiate between positive and negative cues (or nature conditions). In this task, PAT was the only significant predictor of performance, suggesting that it is more sensitive to acute investment of mental effort than HR. Study 2 examined the potential of using the PAT in a biofeedback system where a person is informed of his/her low arousal. The results of a pilot tests showed that individuals were able to comply with the information given by the system, and improved their performance in the intervals following the arousal cues it provided.

We experienced some problems in the construction of the biofeedback system, which prevented us from testing it on a larger sample in the time frame of the grant. Otherwise, we have accomplished our intended experimental goals.

2. Status of Subjects:
Total number of subjects participated: 93
Total number of subjects specified in the protocol: 400 (maximum)
Male/female ratio: 50.5% Male
Number of subject withdrawals (include reasons for withdrawal): No withdrawals
Subject complaints: None
Adverse events: None

3. Summary of Resources:
Salary : $23,083
Participants in experiments : $1,019
Supplies and materials : $2,458
Equipment : $11,054
Overhead 19% : $7,147
Total : $44,764

4. Objective: The objective of study 1 has been met. It is now clear to us that PAT is a good predictor of effort in tasks requiring sustained attention; but it is even better (compared to a general autonomic measure such as Heart Rate) in fast paced tasks involving non-trivial cognitive load. The objective of study 2 has been partially met. We know of the potential of the PAT for biofeedback, but our demonstration of it was only on a case study basis (see description below).

5. Results:

Study 1a (vigilance task): In this study we administered a vigilance task, which included rare events. This is similar to some Air Force tasks such as Radar Operation and Guard duties. The experimental task was a Go/No-GO task with two cues of "friends" (in the form of two digit numbers) and 2 of "foes" which appeared rarely (twice in 100 trials). The meaning of each cue was known in advance and also constantly presented to the player. Peripheral Arterial Tone (PAT) and Heart Rate (HR) were measured. In this way, we evaluated the potential of these physiological measures to provide online indications of mental arousal that affects task performance. The stimuli had a latency of 1 second, response window of 2 seconds, and 10 seconds between each event. The rate of commission errors was 1% and the rate of omission errors was 31% in line with the difficulty of detecting the rare event.

Findings:

Table 1: Associations between physiological measures and performance measures in Study 1a.

Mental arousal as implied by	Vasoconstriction (low PAT amplitude)	Heart Rate (high HR)
Misses	-0.28*	0.29*
False Alarms	-0.04	0.26*

As indicated in Table 1, both measure (PAT and HR) predicted task success, with PAT vasoconstriction predicting misses only. However, note the direction of the correlations. Whereas high arousal as denoted by heart rate was associated with *more errors*, high arousal as measured by PAT was associated with less misses. This implies that the two measures together assess complementary processes that are associated with performance. It appears that PAT assesses cognitive effort whereas HR assesses anxiety.
The association between arousal measures of HR and PAT was about -0.30: Those with high HR had lower arousal denoted by vasoconstriction. This also reflects the complex relation between the measures. A multiple regression analysis did not, however, reveal an improvement in the prediction of misses and false alarms when both measures are used together as predictors.

Study 1b (fast pace task): This task was similar to the one employed in Study 1a with the following differences. First, the pace was much faster, with a latency of 0 seconds, 2 seconds to respond, and 4 seconds between trials. Secondly, the task involved larger cognitive demands. It had 10 different cues in the form of two digit numbers. Initially, the participants were not given any information concerning the meaning of the two digit numbers but were only told that pressing the mouse key while some cues are presented can lead to gaining money, while pressing the mouse while others are presented can lead to losing. The participants had to learn the value of each cue from their experience. In actuality, 5 cues led to positive outcome and 5 led to negative outcomes. The rate of commission errors was 19% and the rate of omission errors was 4%.

Findings:

Table 2: Associations between physiological measures and performance measures in Study 1b.

Mental arousal before event as implied by	Vasoconstriction (low PAT amplitude)	Heart Rate (high HR)
Misses (Omission)	0.30*	-0.12
False Alarms (commission)	-0.42*	0.05
Trials until obtaining 8 cumul.	0.09	0.12

It appears that in the fast pace Go/No-Go task used in Study 1b, HR was not a good predictor of performance, whereas PAT predicted both misses and false alarms. This is consistent with the known direct innervations of the PAT signal by the sympathetic system which is a fast-changing

component of autonomic arousal. In contrast, HR is also affected by the parasympathetic system which has longer latencies and can contain more residual effects.
Note that the direction of the association with the PAT is different than in Study 1a. In particular, the PAT component was associated with cautiousness leading to fewer false alarms, whereas in Study 1a it was associated with fewer misses. This appears to be inconsistent but there is a simple explanation to this fact. In the task used in Study 2 participants had to avoid negative outcomes 50% of the time. As losses loom larger than gains (Baumeister, Bratslavsky & Finkenauer, 2001; Rozin & Royzman, 2001) effort was associated with making less selections of the wrong numbers. The functional significance of the PAT signal therefore changes in light of the task directive.
The association between arousal measures in this study was also about -0.30: Those with high HR had lower arousal denoted by vasoconstriction.

References

Baumiester, R. F., Bratslavsky, E., & Finkenauer, C. (2001). Bad is stronger than good. *Review of General Psychology, 5*, 323-370.

Rozin, P., & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review*, 5, 296-320.

Study 2

This was a replication of study 1 with biofeedback based on PAT. The biofeedback was implemented in the following way. Participants heard a sound in their ear-phones whenever their arousal level dropped beyond a baseline level. This baseline level was determined according to their performance of a simple two-cues Go/No Go task in the beginning of the experiment. Drops of *X* standard deviations from the individual participant's average PAT resulted in a signal that was delivered in the form of a sound to the participant's earphone. Unfortunately, there were many technical problems in constructing this device so only six participants were piloted in the final system (several more participated in earlier pilots). In the pilot, the number of standard deviations was varied (3 to 2 participants, 2 to two and 1 to two). The results were as follows. For 3 SDs no drops from baseline performance were recorded (and consequently no signals were emitted). For one SD there were continuous drops resulting in constant signals (in about 20% of the trials). For 2 SDs, one participant obtained 5 signals and another obtained 6 signals. We therefore considered the two SDs as an appropriate cutoff for identifying occasional slips of attention. Figure 1 and 2 include the case results for one of these two participants.

Figure 1 shows an average increase in arousal following the biofeedback signal. Figure 2 shows that the arousal (indicated by vasoconstriction) before errors was lower than before successes (consistent with the finding of Study 1). Thus, we have demonstrated the potential of the PAT signal in biofeedback but the findings should only be considered a pilot test due to the small number of participants.

Figure 1a: Vasocontriction (-volts) before and after the biofeedback signal. The error bars denote the standard error.

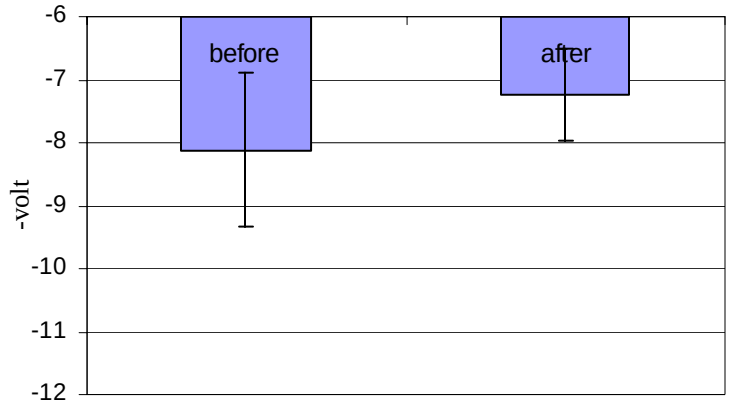
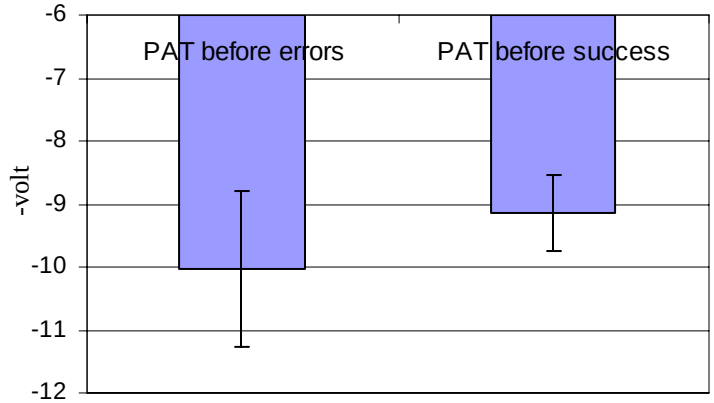


Figure 1b: Vasoconstriction (-volt) before and after errors. The error bars denote the standard error.



Summary of all three studies in relation to the Air-Force:
Heart rate as well as other general indices of arousal (such as breathing rate) are often used as online indicators of cognitive effort and stress in various setting ranging from performance of critical tasks to diagnosis of stress disorders such as PTSD. However, the HR is a very general signal that is relatively insensitive to small changes in effort due to task demands. Moreover, it is a relatively rough signal resulting from two separate channels of the autonomic system. In the current study we have demonstrated the potential of an easy to measure index of sympathetic activation (PAT) to assess ongoing workload in a high pace task (Study 1b). In a slower pace task (Study 1a), the HR was sufficient to predict performance and it was cross-correlated with the PAT so that no advantage of using the PAT was observed. In summary, the physiological

measures for assessing arousal should be determined according to the task type, and specifically consider whether it is a slow pace vigilance task or a high pace task requiring non-trivial dynamic cognitive efforts. Our second study revealed the potential of a biofeedback device based on the PAT signal for not only tracking performance but also for affecting it.

Parts of this study are planned to appear in a book chapter. ["Tracing Intuitions", edited by A. Glockner and C. Witteman (Psychology Press)]. This chapter is in progress.

We are also in the process of summarizing these results in a paper that will be submitted to a scientific journal.

Eldad Yechiam, PhD
Principal Investigator

Attachments:
1. Original, signed informed consent documents